









# Development of Process Engineered Fuel From Polymer Waste

A Major Project Submitted to Faculty of Technology of  
University of Delhi

Towards the Partial Fulfillment of the Requirements  
For the Award of the Degree Master of Engineering in  
Polymer Technology

*Submitted by :*

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## **CERTIFICATE**

This is to certify that the Major Project entitled "Development of Process Engineered Fuel From Plastic Waste " is being submitted by Vinod Kumar Sharma in the partial fulfilment for the award of "Master of Engineering Degree in Polymer Technology" to the Delhi College of Engineering, University of Delhi, Delhi, in record of bona-fide work carried out by him under our guidance and supervision.

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*This is to certify that Mr. Vinod Kumar Sharma student of M.E. (Polymer Technology), Delhi College of Engineering, University of Delhi has carried out the major project entitled “**Development of process engineered fuel from polymer waste**” at **Shriram Institute for Industrial Research, New Delhi** under our guidance and supervision*

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## **ACKNOWLEDGEMENT**

It is my great pleasure to express my sincere thanks to Dr P.B. Sharma, Principal (Delhi College of Engineering Delhi), Dr G.L. Verma, HOD Polymer science and chemical technology, (Delhi college of Engineering) and my guide Dr A.P Gupta, Dept of Applied chemistry and Polymer Technology, Delhi college of Engineering, (University of Delhi), for their guidance keen interest, constructive and valuable suggestions throughout the course of the project their constant encouragement gave me the confidence and strength to complete this work.

I would like to thank to Dr R.K Khandal, Director, shriram institute for industrial research for providing me an opportunity to work in the organization. I would extend my profound gratitude to Dr U.K Niyogi, Deputy Director, (MSD), and Dr R.K Dewan, Assistant Director(MSD) for his inspiration, interest, guidance and suggestion throughout the duration of my project. I would sincerely like to thank Mr Sanjay Rajput, senior scientist, Dr Meenu Sethi, Research associate, (MSD) for encourage during my project work and also helping in write this report I would like to thank Mr Vinay Jain and Dr Minakshi Verma (MSD), for providing me technical guidance and support time to time during my project work.

I express my deepest acknowledgement to the staff of SRI who was quite helpful during my project and gave me valuable support and provided friendly environment.



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## **AIM OF THE PROJECT**

To develop “process engineered fuel” from plastic waste

For which the following work to be carried out

- Shredding of plastic waste and non plastic waste
- Mixing of plastic and non plastic waste in different proportion
- Extrusion of different mixing batches
- Characterization of these batches





## **1.1**

### **Energy scenario in India**

Self reliance in energy is a vital factor in the development of a nation. India ranks sixth in total energy consumption in the world. In per capital terms, its consumption is only about 20% of the global average. This means that the requirement of energy in India is bound to grow at a much faster rate with India targeting ambitious growth rates of seven to eight percent over the next two decades, its per capital energy consumption will rise in the future. At presently India is facing serious energy shortage and is dependent on import substitute. In India, coal biomass, oil and natural gas are main sources of energy. Among these, coal is a major sources of energy. Among these, coal is a major source of energy, which is mainly used for electricity generation. It is reported that 75% of the coal consumed in the country goes for power generation and approximately 70% of the total electricity generation is derived from coal. It has been projected that the electricity demand would grow at approximately six percent per annum. It is estimated that coal production in India would plateau in next ten years and the coal reserves would hardly last for another forty years. The oil and gas reserves also have a remaining life of about 50 years only. If the present trend continues the gap between energy demand and domestic production is likely to be widen, leading to a growing dependence on energy imports. The broad overall conclusion arising from these data is that there is a continual rise in energy demand in the near future. The energy crisis has clearly shown that dependency on imported forms at energy should be reduced to the minimum and the fossils fuels, which are limited, will become increasingly costly and scarce in the coming future. In the present circumstances hence, it is imperative to utilize the renewable resources for deriving energy. The key to energy challenge is to ensure adequate availability of energy for all, delivered in the most cost effective manner without compromising on the long term interest of the country and quality of the environment. In this respect converting waste into energy is a great idea in terms of conservation of fossil fuel and renewable source of energy and also to close the environment.



## 1.2

### PLASTIC WASTE SCENARIO IN INDIA

The rapid rate of urbanization throughout the world has led to increase in waste which in turn poses greater difficulties for their disposal. Now a days plastics are being used in almost all the sectors like automobiles, agriculture, medical, packaging, electronics, etc.

Today there is a staggering demand for plastic products with rising influence and public preference for western consumerism. It has been reported that per capital plastic consumption has increased to 5kg in 2005 the growth of Indian plastic industry has been phenomenal.

The plastic industry growth rate is higher in India than anywhere in the world. Among the various sectors packaging presents a major growth area where there has been a continuous demand for plastics 52% of the total plastics produced in India is utilized for packaging. It has been estimated that virgin **LDPE** consumption for carry bag is 31,000 tones. This expansion of plastic consumption is having a significant impact both visibly and invisibly on the environment and society in the country.

It is reported that 36.5 million tons/year (36.5 kg/individuals) of municipal solid waste (**MSW**) is generated in the country. The plastic content of the overall waste is reported to be in the range of 1-4%. It has been estimated that annually 2 million tons plastic waste is generated in India. Among all the plastic waste generated 60% is being recycled and remaining 40% waste is uncontrolled.

Considering the post consumer waste available for current year 800,000 tons of waste remains as litter, or finds its way to open dumping grounds creating a lot of environmental problems. In the present circumstances, energy recovery from plastic waste could be beneficial in



two ways, first for the conservation of fossil fuels and second for the problem of disposal of plastic wastes

Plastics are typically derived from petroleum or natural gas giving them a stored energy value higher than any other material. Plastic wastes because of their high heating value, provide an excellent source of energy. Quaternary recycling of plastics can replace a part of the conventional fuels such as wood, coal or fuel oils.

The plastic waste products can therefore be used either as such or they can form a part of a mixed combustible waste fraction for use as solid fuels for the boilers and the power plants. Plastics used for packaging such as polyethylene and polypropylene can generate twice as much energy as derived from commonly used coal and almost as much energy as obtained by the fuel oil. Recognizing the high energy value of plastics it is interesting to process plastic waste and convert it into solid fuels with improved characteristics storage, transportation and burning and controllable pollution conditions, conversion of plastic waste to solid fuels is an economically attractive option for post use plastic scrap especially in the regions where large quantities of feed stocks are locally available.

Plastics having a high hydrogen to carbon ratio can be utilized as an efficient alternate source of heat energy in comparison to coal and other biomass fuels. There is a great potential of an effective translation of the molecular energy (potential energy) of plastic waste to heat energy by way of compaction and controlled burning.



## 1.3

**MUNICIPAL SOLID WASTE**

The composition of MSW has a decisive impact on the environment, whether it is dumped in land fills, composted, or incinerated, Different societies generates garbage with different ingredients, but the average MSW in North America and Europe is composed of the following (% by weight)

Paper, wood and cellulosic products	41
Plastic, film, diapers, others	9
Leather, rubber	2
Textiles	4
Garden waste	8
Ceramics, stone products	2
Glass	10
Steel cans, ferrous metals	2
Non ferrous metals (Aluminum cans)	2
Food waste	15
Miscellaneous	5

The organic content of the average household can vary from 65 to 75 %. This portion of the MSW is combustible and can be incinerated to generates energy in the form of steam and electricity. Normally the inorganic portion is non combustible and has a very low calorific value.





**Zone wise municipal solid waste survey in Delhi (in %)**

**Table 1**

Location	organic	paper	plastic	silt	rags	Glass/crockery	Metal
Mangolpuri	9.7	2.7	1.9	70.1	12.4	2.3	0.9
Ahta Thakur das	56	86	11.1	23.0	11.4	8.6	6.7
Green park	40.7	5.9	4.7	34.2	4.0	4.8	1.7
Subhas nagar	5.5	8.7	6.2	56.9	6.5	6.1	4.4
Trilok puri	10.6	9.7	5.8	39.4	5.6	8.1	3.2
Navin shahdara	9.6	2.7	2.0	69.9	12.6	2.3	0.9
Shakur pur	3.7	4.1	3.3	72.0	0.7	3.3	3.4
Chandni mahal	42.1	3.8	1.3	19.1	10.1	4.4	1.2
Outran line, Delhi	57.7	7.7	5.8	11.5	7.7	5.8	3.8
Qutab road	5.6	8.6	11.2	22.9	13.0	9.1	6.8
Arya samaj road kureni	6.0	10.5	9.9	16.5	13.3	16.9	14.8
Sundar nagar	8.01	6.1	48.0	24.9	3.7	5.0	1.2



## **1.4 Land fills**

Landfills are very important factors in the safe disposal of MSW. Their design, operation, and management are essential for a clean and safe environment. It is impossible to anticipate zero garbage after the reusing, the recycling or the incineration of waste. Substantial quantities will still accumulate and must be disposed of. The waste generated by the average household contains nearly every chemical conserved by both nature and humanity, it is expected that some of these chemicals will react with each other to form new compounds. Heat, pressure, moisture, and metals are activators for such reactions. The land fill becomes a massive chemical factory producing hundreds of new chemical compounds, many of which continue to react with other chemicals, thus initiating a chain reaction in most of the land fills these reactions are uncontrolled and very difficult to monitor since the process is very slow.

The decomposition of MSW in landfill to methane and corbondioxide with many toxic compounds, complex metal salts, and organometallic compounds leach out and are carried by under ground waters to rivers and lakes land fills do not eliminate the toxic substances contained in the garbage they merely store them to be reintroduced into the ecosystem. Dioxins, poly chloro biphenyl (PCB), and furans contained in MSW or industrial waste are recirculated to out food chain via the leachate from out landfills.

Methane and  $\text{CO}_2$  are the most common greenhouse gases. Methane is 25 times more effective as a green house gas than  $\text{CO}_2$



The atmospheric residence time of CO<sub>2</sub> is between 2 to 7 years and methane has residence time of 5-10 years. It is estimated that land fills emit 6—10 times the amount of greenhouse gases as a modern EFW facility. Incinerators do not emit methane gas.

Methane gas evolving from land fills can be combusted to produce energy, but since the decomposition process could be slower than the demand and by the power plant such energy recovery is unreliable as an energy source

Many communities oppose the presence of land fills in their areas at Jurisdiction, causing a shortage in land fill sites. At the rate garbage is being generated, in few coming years most of the big cities will have no space to dump their waste.

### **Estimated quantity of waste generated in India**

**Table 2**

SN	Waste	Quantity
1	Municipal solid waste	27.4 Million tones/year
2	Municipal liquid waste (121 class I and II cities	12,145 million litres/day
3	Distillery (243 numbers)	8,057 kilo litres/day
4	Press mud	9 million tones/year
5	Food and processing waste	4.5 million tones/year
6	Willow dust	30,000 tones/year
7	Dairy industry waste (COD level 2 kg / m <sup>3</sup> )	50-60 million litres/day
8	Paper pulp industry waste (300 mills)	1,600 m <sup>3</sup> waste water/day



## 1.5 Recovery of Energy from waste Polymer

All matter has energy stored in its molecular structure. Molecules are joined by bonds which are a type of energy. Every material has a specific energy level that holds it together. If this level is surpassed it disintegrates into smaller particles with the release of the stored energy. The release of this potential energy is in direct relation to the level of activation required to decompose the material

Organic matter is made up of carbon atoms linked by single, double or triple bonds. Every material is combustible at a certain temperature. Organic matter has a relatively low decomposition temperature compared to inorganic compounds. All the conventional fuels are based on organic molecules. The heat content of an organic molecule depends on the number of carbon atoms in the molecular chain and the complexity of the molecular structure (linear, branched, cyclized, cross linked). The basic components for organic compounds are carbon hydrogen and oxygen but many may carry other elements such as chlorine, sulphur, nitrogen and bromine other organic compounds like with inorganic elements to form organometallic compounds and salts. When organic compounds are decomposed by heat many gases are emitted.

Some inorganic elements add thermal stability to the organic molecule as chlorine imparts flame retardancy to the molecule. Such molecules are decomposed only at higher temperatures.

Paper which is mixture of cellulosic organic chains with inorganic salts has a medium calorific value. Plastics in which carbon atoms are polymerized into very long chains have about triple calorific value than paper and we expect plastic to generate more heat when incinerated.

### **Estimated renewable energy potential in India**

**Table 3**

SN	Energy source	Estimated potential
1	Bio energy	17,000 MW
2	Draught animal power	30,000 MW
3	Energy from MSW	1000 MW
4	Bio gas plant	12 million plants

Source – ministry of Non conventional energy source





## 2.0

**Experimental details**

1. Procurement of raw material—Raw material was procured from different sources of polyethylene bags. Waste were procured from kabariwala and west market.

**Raw materials and their sources****Table 4**

S.N.	Material	Source	Remarks
1.	PE waste	Kabari wala	
2.	Saw Dust	Band saw mill	Mixture of different varieties
3.	Coal	Local market	Industrial grade coal
4.	Waste paper	House Hold waste	Corrugated fibre box waste
5.	Leaf waste	Collected from field	Mango and Eucalyptus trees

## 2. Shredding of Raw materials (waste)

Shredding was done by the shreddure. Which is a mechanical device and utilized to reduce the size of films paper. Polymer includes multilayer films, cross-laminated films, and HDPE container. The shredder has been designed to griend all kinds of plastic waste and other waste to desired size. The shredder has different capacity with six blades of different length. It can be possible to use this machine for grinding of woven sacks waste, PET bottle waste, paper waste etc.

Now we have the materials for mixing.

1. Shredded PE waste (bags, films etc)
2. Leaf waste (mango, Eucalyptus)
3. Saw dust
4. shredded paper waste



## 2.1 **Mixing**

### **Mixing the PE waste with Non plastic waste:-**

Mixing was done by the high speed mixture.

**Mixing with leaf waste:-** The shredded plastic waste and leaf waste were weighed and mixed in different composition. The material was mixed for 10 minutes and then discharge from side opening.

The composition of fuel system are given in table

**Table 5**

SN	B.code	PE waste%	Leaf waste%	Total quantity
1	ELW—40	60	40	2 KG
2	ELW—30	70	30	2 KG
3	ELW—20	80	20	2 KG

### **Mixing with paper waste**

Exactly weight the paper waste and plastic waste in different proportion and fed into the high speed mixer mix then for about 10 minutes and take off the materials from the side opening. The ratio of plastic and non-plastic waste was as follows:

**Table 6**

SN	B.code	PE waste%	Paper waste%	Total weight
1	EPW—40	60	40	2 KG
2	EPW—30	70	30	2 KG
3	EPW—20	80	20	2 KG



### Mixing with saw dust:-

Shredded PE waste and saw dust were weight and fed to the mixer and mixed for 10 minutes and collected the materials in bags. The ratio of saw dust and PE waste are as follow

**Table 7**

SN	B.code	PE waste%	Saw dust waste%	Total weight
1	ESD—40	60	40	2 KG
2	ESD—30	70	30	2 KG
3	ESD—20	80	20	2 KG

Now we have 9 mix batches of PE waste with Non plastic waste (paper, saw dust, Leaf waste) and a pure of PE waste for extrusion.

### Extrusion:-

Extrusion was done by the extruder.

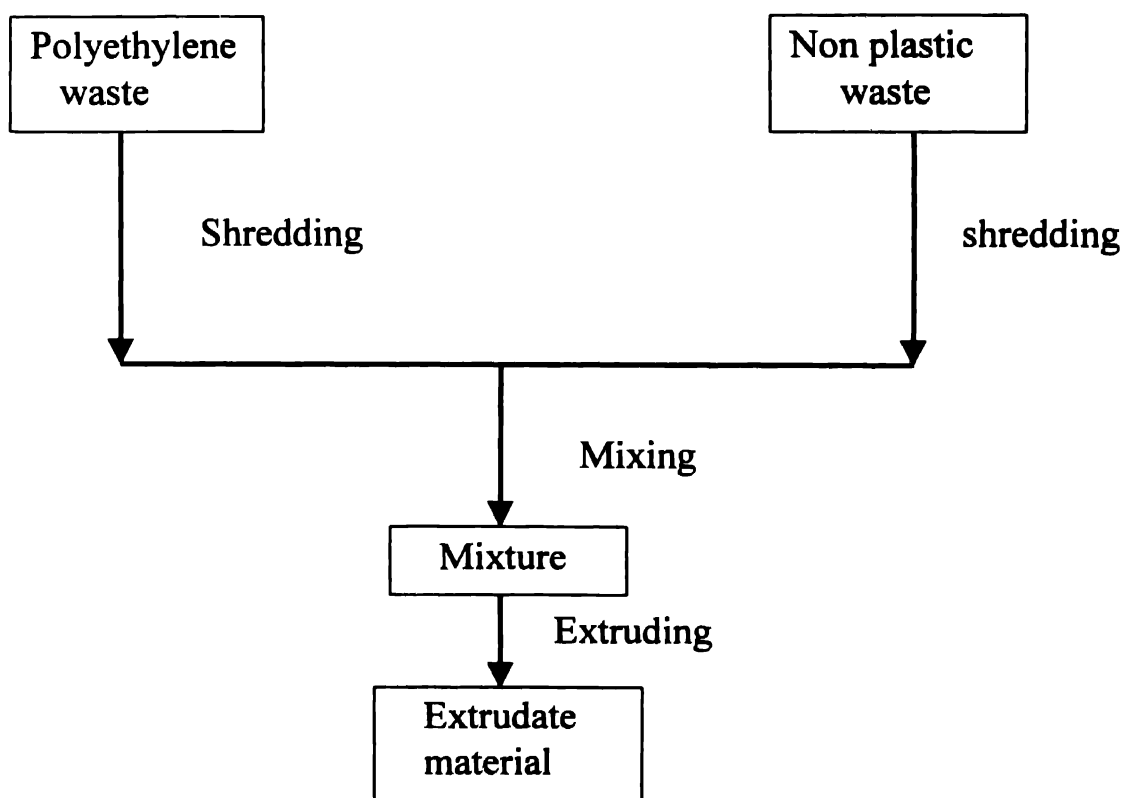
Extruder is a device by which the formulated waste will be compacted under the influence of screw and heat. The compacted material will be pushed out in the form of rods through a dye of desired dimension. The machine have provided with a die face cutter which will chop the rod obtained as above to the desired size. The chopped material will be cooled by blowing air. The machine has capacity 100 kg/hrs and has a broad feeding system that can easily insert fluffy material into the barrel of the machine. The size of the screw is 65 mm and has an automatic temperature control arrangement. The machine



will be utilized to compact the formulated waste at an optimized temperature. So that the compacted fuel should not come out in the complete molten form the advantage of getting the compacted fuels in semi molten form is to get the Extruded rod in specific hardness so that it can be chopped to desired size.

## **2.2 Extrusion of fuel system**

The mixed fuel batches were than extruded to form lumps for extrusion the mixed batches was fed to the hopper. The temperature of three different zone was  $130^{\circ}\text{C}$ ,  $150^{\circ}\text{C}$ ,  $120^{\circ}\text{C}$  and speed of feeder was adujested as per requirement. After extrusion well mixed extrudate was obtained which was stored for characterization. The flow sheet for the total process is given in fig.



Flow diagram for preparation of fuel system  
Figure. 1





**Extruded batch****Table 8**

SN	Batch code	PE waste%	Leaf waste%	Paper waste %	Saw dust %	Total weight
1	ELW-40	60	40	--	--	1 ½
2	ELW-30	70	30	--	--	“
3	ELW-20	80	20	--	--	“
4	EPW-40	60	--	40	--	“
5	EPW-30	70	--	30	--	“
6	EPW-20	80	--	20	--	“
7	ESD-40	60	--	--	40	“
8	ESD-30	70	--	--	30	“
9	ESD-20	80	--	--	20	“
10	E-100	100	--	--	--	“
<b>Non extruded batch</b>						
11	Leaf waste		100	--	--	“
12	Paper waste		--	100	--	“
13	Saw dust		--	--	100	“
14	Coal		--	--	--	“



## 2.3 Characterization

### 2.3.1 Calorific value

Calorific values of samples were determined as per IS: 135 70- 70 using bomb calorimeter combustion bomb and crucible were washed with distilled water and dried in an oven, the sample was accurately weighed and placed in the crucible and the crucible was placed in combustion bomb and 10ml of water was added to combustion bomb. The combustion bomb was then filled with oxygen to give a pressure of  $3.0 \times 10^6 \text{ N/M}^2$  and then this combustion bomb was put into water chamber connected the wires. Note the initial reading of temperature should be fixed for 1 min. The sample was then fired by pressing the ignition button. Then started the fire and then note the final reading of temperature should be fixed for 1 min

The calorific value was calculated with the help of following formula.

$$\text{Calorific value} = \frac{(f - I) \times F}{W}$$

Where       $f$  = Final reading of temperature  
                $I$  = Initial reading of temperature  
                $F$  = Factor  
                $W$  = Weight of sample

We have to determine the calorific value of all 14 batches



### 2.3.2 Sulphur content

After determination of calorific value in bomb calorimeter the remaining water was taken into a beaker.

The cylinder was washed with distilled water and all the washing were collected in the same beaker 10 ml of conc.HCl was then added and boiled for some time. To this solution about 10 ml of 10 %  $\text{BaCl}_2$  solution was added and then heated again (near to B.P). The solution was then cooled and precipitate were allowed to settle down for about 4-5 hrs.

Precipitate were then filtered using what man filter paper 42 precipitate washed with distilled Boiling water to remove chloride present there in. The precipitate taken in the crucible and subjected to ignite at  $850^\circ\text{C}$  in muffle furnace. After ignition all sulphur content was obtained in the form of  $\text{BaSO}_4$

The sulphur content is calculated as follow

$$\text{Percentage sulphur} = \frac{32}{232} \times W \times 100$$

Where W = Weight at  $\text{BaSO}_4$  after ignition. We have to determined the 14 sample



### **2.3.3 Ash content: -**

Every solid fuel when burns some residue is left. Different solid fuel give different quantity of Ash content. In better fuel the quantity of Ash. Should be minimum which increases the efficiency of fuel. For determining the ash content the sample was taken and weighed and put into porcelain crucible and then heated in a preheated hot air oven (100°C) to remove the moisture. The sample then accurately weighed and kept in the muffle furnace at temperature 700°C for 5.0 hours After 5.0 hours. Sample were taken out from the muffle furnace cooled in the desicator. After 2.0 hours the sample were then weighed and ash content calculated from the following formula

$$\text{Percentage Ash content} = \frac{(\text{Initial Weight} - \text{Final Weight})}{\text{Initial Weight}} \times 100$$

### **2.3.4 Moisture content: -**

The non plastic waste (Paper, Saw dust, leaf waste) is hygroscopic in nature and therefore, they have some percentage of moisture in them. Hence, it is necessary to determine moisture content of prepared fuel system. For moisture content determination, samples were ground to small pieces in heavy duty grinder. The sample were accurately weighed in a cleaned and dried weighing bottle and then kept in a hot air oven, preheated at 100 ± 5°C, for 4.0 hours. After 4.0 hours the sample were removed and cooled in a desicator and weighed again. The process was repeated till constant weight is obtained. The moisture content is calculated as follows:

$$\frac{\text{Weight before drying} - \text{Weight after drying}}{\text{Weight Before Drying}} \times 100$$





### **2.3.5 Emission studies:-**

Emission studies were carried out on a locally manufactured combustion system. The system comprised of one combustion chamber having one side opening for providing excess air into fuel chamber. A chimney was fabricated with lower diameter equals to or more than the mouth of combustion chamber. The chimney was 30" long and it was having one side opening to collect the gas samples. The gases coming out from the chimney were sent to Analyzer for determination of CO, NO<sub>x</sub> and SO<sub>x</sub>.

For determination of emissions coming out from combustion of fuels, a fixed quantity of each fuel (i.e. 1/2 kg) were taken. The fuel sample was kept in the combustion chamber and burned. The excess air was supply from the side opening. The amount of air supplied was kept constant for each fuel system. After 10 minutes of burning the emitted gas samples were collected from side opening with the help of a vacuum pump. The gases were sent to the analyzer for determination of SO<sub>x</sub>, NO<sub>x</sub> and CO. The analyzer directly gives the value of SO<sub>x</sub>, NO<sub>x</sub> and CO in ppm level.

### **2.3.6 Burning Behaviour**

Burning behaviour of all the samples were determined using the locally fabricated combustion chamber. In the burning behaviour different parameters were observed. These are:-

- 1 Time taken to initiate burning ( $T_1$ ):- This is the time taken by the fuel to start burning.
- 2 Time taken to raise the temp. by 100<sup>0</sup>C ( $T_2$ ):- A beaker containing 1 litre water was kept on the combustion chamber. The time taken by fuel to raise the temperature by 100<sup>0</sup>C was note down.



3. Time taken for complete burning ( $T_3$ ):- This is the time taken by the constant weight of fuel to burn completely.
4. Visual observation:- The burning behaviour of fuel was observed visually for dripping, homogenous burning and soot formation.

For measuring burning behaviour equal quantity of each fuel was taken in the combustion chamber and burn with the help of matchstick. The time for each step was noted with the help of stop watch. A beaker containing 1 liter of water was kept on the mouth of combustion chamber. The beaker was covered with aluminium foil to avoid any heat losses. A thermometer was hanged inside the water to note the rise in temperature. Dipping, homogenous burning and soot formation were observed manually and ranked from lower to highest.

### **2.3.7 Elemental (C,H,N) Analysis**

For elemental analysis the sample were first powdered by a drill machine. Around 1 gm of each sample was powdered. For C,H,N analysis, 6-10mg of sample was weighed in an aluminium foil piece. The sample was then wrapped in the foil and then analyzed on a C, H, N Analyzer. The sulphur was determined using bomb calorimeter method. The oxygen was calculated by simple difference.



### 3.0

## Result and Discussion

### 3.1 Calorific value

Table represents the calorific value of all fuel samples derived from PE waste with Non plastic waste (Paper, Saw dust, leaf waste)

**Table 9**

SN	Sample code	Calorific value cal/gm
1	ESD-40	7874.00
2	ESD-30	8619.50
3	ESD-20	9294.60
4	ELW-40	7494.29
5	ELW-30	8935.67
6	ELW-20	9039.73
7	EPW-40	7633.20
8	EPW-30	8065.41
9	EPW-20	9625.45
10	E-100	9643.34
11	Coal	4729.05
12	Sawdust	5909.03
13	Leaf waste	4741.60
14	Paper	2615.65



It was observed that the calorific values decreases on increasing the Non plastic waste. The calorific value for pure PE waste (E-100) is highest.

On increasing the non plastic waste calorific value decreases, but it is higher than calorific value of coal. It is observed that at 40% non plastic waste concentration calorific value is still higher than coal. It is also observed that amongst all the non plastic waste, fuel system incorporating saw dust has highest calorific value, which is attributed to higher calorific value of saw dust

### **3.2. Ash content:-**

Ash content of different sample prepared from PE waste with Non plastic waste is given in the table-10.

**Table 10**

SN	Sample code	Ash content%
1	ESD-40	3.084
2	ESD-30	2.672
3	ESD-20	.229
4	ELW-40	8.538
5	ELW-30	6.552
6	ELW-20	5.867
7	EPW-40	2.778
8	EPW-30	1.937
9	EPW-20	1.531





Table 10 Continue

10	E-100	0.633
11	Coal	42.670
12	Saw dust	7.637
13	Leaf waste	13.290
14	Paper waste	7.660

It is observed from the table that the Ash content decreases with increasing polymer waste in the fuel system. It is observed that amongst all the fuel systems the fuel with paper waste has lower Ash content and fuel with Leaf waste has higher Ash content on comparing with coal it is observed all the fuel system have very low ash content. It is observed that even at 40% non plastic waste loading ash content is considerably low as compared to coal. Comparing all the properties with coal it is inferred that upto 40% non-plastic waste loading does not deteriorate the properties of plastic waste and Ash and moisture content and calorific value are much better as compared to coal. Therefore 40% non-plastic waste incorporation is optimal for preparing fuel system.



### 3.3 Moisture content: -

Non plastic waste added in the fuel system have moisture content. The moisture content of all the samples is given in table.-//

**Table 11**

SN	Sample code	Moisture %
1	ESD-40	1.440
2	ESD-30	0.945
3	ESD-20	0.569
4	ELW-40	1.786
5	ELW-30	0.959
6	ELW-20	0.712
7	EPW-40	0.690
8	EPW-30	0.699
9	EPW-20	0.585
10	E-100	0.126
11	Coal	1.224
12	Saw dust	8.824
13	Leaf waste	9.189
14	Paper	4.176



It is observed from the table that moisture content of the fuel system increases with increase in the non plastic waste. The fuel system prepared by incorporating paper waste shows minimum moisture content while the fuel system incorporating leaf waste has highest moisture content. This is attributed to inherent moisture present in leaf waste. It is observed that as compared to coal, the fuel system containing higher percentage of non plastic waste have higher moisture content. The problem of moisture can be overcome by predrying the raw material before processing.

### **3.4 Emission studies consideration:-**

Air emission analyses based on available data indicated that sulphur dioxide, nitrogen oxide and carbon monoxide emission decreased as compared to coal.

Based on the current levels at PEF production the overall impact on environmental emission from cofiring PEF with coal is small. However, relatively large reductions in the total amount of sulphur dioxides, nitrogen oxides and carbon monoxide could be achieved if the amount of PEF used to replace coal could be significantly increased. Greenhouse gas emissions are reduced when PEF is substituted for coal.

To investigate the environmental impact the fuel, emission studies were carried out. The study was carried out on a locally fabricated apparatus, the apparatus consisted of a combustion chamber, source of air supply and a chimney for collecting the emitted gas samples. The emission data was generated at laboratory as well as industrial scale. The fuel sample were taken in constant weight and burned in the combustion chamber with excess air supply. The chimney was placed on the combustion chamber. The gases coming out from the chimney were collected from the side opening and then sent to Enerac-3000 F Analyzer for measuring  $SO_x$ ,  $NO_x$ , CO



**Table 12**

SN	Sample	NO <sub>x</sub> (PPM)	CO (PPM)	SO <sub>x</sub> (PPM)
1	EPW-40	305	315	NIL
2	EPW-30	324	401	NIL
3	ELW-40	551	640	NIL
4	ELW-30	560	647	NIL
5	ESD-40	321	450	NIL
6	ESD-30	348	478	NIL
7	Coal	732	804	246

Air pressure = 3 kg/ cm<sup>2</sup>

Sample weight taken – 500 gm

The emission studies were carried out on optimized fuel systems. It was observed that as compared to coal the prepared fuel emit lower amounts of NO<sub>x</sub>, CO, SO<sub>x</sub> generation is nil in fuel system while coal generates 246 ppm of SO<sub>x</sub>

**Industrial Trials at M/S Paras Industries Ltd.** Industrial trials were carried out on at a boiler M/s paras industries Ltd, 20 kg of plastic fuel and 20 kg of coal were burnt in two experiments. Under similar conditions. The emission coming out form burning of PEF was compared with the coal. The results are as under:





**Table 13**

<b>Parameters</b>	<b>Fuel system EPW 40</b>	<b>Coal</b>
Fuel quantity	20 kg	20 kg
Initial burning time	5 min	8-10 min
Emission data		
CO	1204	877
SO <sub>x</sub>	0	130
NO <sub>x</sub>	78	87
SPM	351	135
Time taken for steam Generation	37 min	90 min
Temp at stack	800°C	350°C
Ash content	1.0 kg	7.0 kg

It was observed that prepared fuel system require less time for burning initiation and steam generation. The calorific value of the fuel system was also higher which is observed by high stack temp. in case of emitted gas, fuel prepared from plastic waste does not emit SO<sub>x</sub> and NO<sub>x</sub> concentration is also lower as compared to coal. But it was observed that CO and SPM concentration is higher in case of prepared fuel systems. This is an indication of incomplete combustion, which is attributed to inadequate air supply. The boiler was not having any provision for excess air supply. However the fuel can combust efficiently on a large boiler which has provision for excess air supply.



### 3.5 BURINING BEHAVIOUR

The fuel system prepared from only plastic wastes have the problem of dripping. To overcome dripping problem non plastic waste were incorporated into fuel system. Table shows the results of burning behaviour of the fuels

**Table 14**

SN	Sample code	Burning behavior	T <sub>1</sub> Seconds	T <sub>2</sub> Seconds	T <sub>3</sub> Seconds
1	ESD-40	No dripping	50	900	480
2	ESD-30	Partial Dripping	54	780	420
3	ESD-20	Partial dripping	65	720	300
4	ELW-40	No dripping	62	960	540
5	ELW-30	Partial Dripping	57	840	480
6	ELW-20	Partial dripping	51	900	300
7	EPW-40	No	47	1020	540
8	EPW-30	Partial	40	780	420
9	EPW-20	Partial	45	840	420
10	E-100	Heavy dripping	35	720	180

It is observed from the table that on addition of non-plastic waste dripping decreases which is attributed to increase porosity in fuel system. In case of plastic fuel, the surface of the fuel melts and drips,



but on increasing the porosity the air gaps formed help in burning. This leads to homogenous burning and hence less dripping.



### 3.6 Elemental analysis: -

Elemental analysis was carried out on C, H, N analyzer. Sulphur content was analyzed using bomb calorimeter while oxygen is determined by the difference.

The results are given in table as follows.-

**Table 15**

SN	Sample code	C	H	N	S	O
1	ESD-40	66.118	5.519	0.729	NIL	24.550
2	ESD-30	71.948	6.242	0.802	NIL	18.36
3	ESD-20	84.502	9.493	0.677	NIL	5.099
4	ELW-40	62.117	8.301	1.222	NIL	19.822
5	ELW-30	77.174	8.957	0.708	NIL	6.609
6	ELW-20	86.783	9.948	0.355	NIL	2.953
7	EPW-40	57.563	7.438	1.202	NIL	31.019
8	EPW-30	71.114	8.124	1.216	NIL	17.609
9	EPW-20	82.071	8.373	0.317	NIL	7.708
10	E-100	91.034	7.554	0.696	NIL	0.083
11	Coal	50.468	4.395	1.381	1.6	0.0
12	Saw dust	42.536	6.535	2.032	NIL	41.257
13	Leaf waste	41.770	6.483	2.261	NIL	36.196
14	Paper	534.596	5.801	1.707	NIL	50.236





From the elemental data is clear that carbon percentage in all the polymer waste fuel is higher than the coal. As we decrease the non plastic waste in fuel system the carbon percentage increases. Hydrogen percentage in polymeric fuel is also high as compare to the coal with increasing the polymer waste in fuel system the hydrogen percentage increases.

Nitrogen is present in all the samples but decreases with increasing the polymer waste in fuel system. Nitrogen is also present in coal comparable to all samples prepared from polymer waste

Sulphur is found NIL in all polymeric fuel system and in coal there is sulphur present.

Oxygen percentage is found NIL in coal but in polymer waste fuel the oxygen percentage decrease with increasing the polymer waste percentage.



## **4.0 Conclusion**

In this work the possibility of deriving solid fuel from plastic waste was explored. A number of fuel systems were prepared using saw dust, leaf waste and paper waste in different concentrations. The fuel system so prepared was characterized for their calorific value, burning behaviour, moisture and ash contents and emission studies. The various conclusions drawn from the present work is as follows:

1. Calorific value of plastic waste fuel decreases on addition of saw dust, paper waste and leaf waste and is inversely proportional to concentration of non plastic waste.
2. Moisture and ash content increases on addition of non plastic waste and it decreases with decrease in concentration of non plastic waste.
3. Burning behaviour of fuel system improve upon addition of non plastic waste due to increase in porosity.
4. Among the different fuel systems, system having paper waste performs better.
5. The 40% concentration of non plastic waste is optimal to get fuel of desired properties.
6. There is a reduction in NO<sub>x</sub> and SO<sub>x</sub> emission as compared to coal.
7. Carbon monoxide generation is more which can be reduced by providing excess air to the fuel while burning.



8. A number of fuel systems varying in calorific value and burning behaviors can be prepared by varying the type and ratio of non-plastic waste.
9. The fuel can be used as a substitute of coal for boilers, electricity generation, as a substitute of coke in blast furnace and as a household fuel.
10. The study can be extended using other agricultural waste such as rice husk, mustered stem, wheat husk, groundnut shell etc.



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